

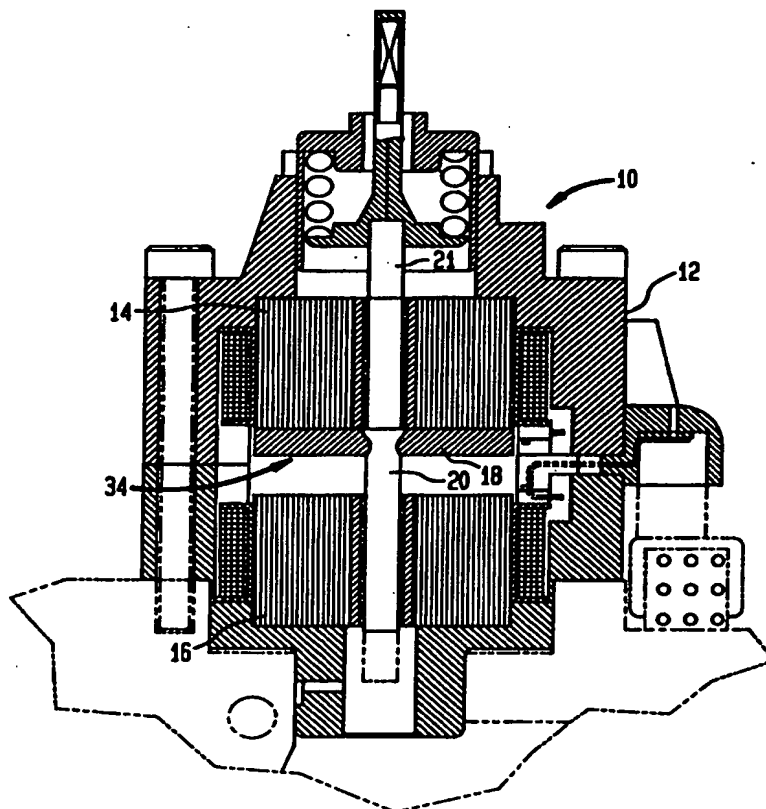
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(54) Title: METHOD OF JOINING A MEMBER OF SOFT MAGNETIC MATERIAL TO A GUIDING SHAFT

(57) Abstract

A method of joining an annealed magnetic armature of an electromagnetic actuator to a shaft is provided. The armature has an aperture therein and the shaft has a reduced cross section portion. The method includes inserting the shaft into the aperture so that the reduced cross section portion is generally adjacent surfaces defining the aperture and applying a force to the magnetic armature to deform a portion of the magnetic armature in a region near the aperture so that material of the armature may engage with the reduced cross section portion of the shaft thereby joining the shaft to the magnetic armature.



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METHOD OF JOINING A MEMBER OF SOFT MAGNETIC MATERIAL TO A GUIDING SHAFT

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FIELD OF THE INVENTION

This invention relates to joining a member of soft magnetic material to a guiding shaft and, more particularly, to joining an annealed magnetic armature of an electromagnetic actuator with a guiding shaft.

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BACKGROUND OF THE INVENTION

In an electromagnetic device, such as an electromagnetic actuator of an electronic valve timing system for a motor vehicle, it is often necessary to join a "soft" magnetic material and a hardened, non-magnetic or magnetic material. Typically, the soft magnetic material is in the form of an armature and is
15 annealed to remove most internal stresses and any carbon which may be within the material. The annealing process accounts for consistent magnetic and mechanical performance characteristics of the magnetic circuit components. In an actuator, the hardened material is in the form of a guiding shaft. The shaft must withstand friction from guide bushings in which the shaft reciprocates. The
20 shaft must also withstand impact with an end of a gas exchange valve and must withstand operational forces while guiding the armature.

The magnetic requirements of the steel used in the armature and the strength required of the steel used in the shaft conflict. Thus, the use of two

different steels for the shaft and for the armature is preferable. As a result, a joint must be made between the two steels.

Typically, the armature-shaft connection is made by brazing or soldering which are performed at high temperature. Increased temperature affects the material properties of both the armature and the shaft. After brazing or soldering, it is often necessary to machine both sides of the soft magnetic material to maintain parallelism between both surfaces and to machine the shaft to true-up the shaft about its axis of rotation. Machining may also degrade the magnetic properties of the soft armature and can soften the shaft material.

Accordingly, there is a need to join a soft magnetic material to a hardened material while maintaining magnetic properties of the soft material and not softening the hardened material.

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SUMMARY OF THE INVENTION

An object of the present invention is to fulfill the need referred to above. In accordance with the principles of the present invention, this objective is obtained by providing a method of joining an annealed magnetic armature of an electromagnetic actuator to a shaft. The armature has an aperture therein and the shaft has a reduced cross-section portion. The method includes inserting the shaft into the aperture so that the reduced cross-section portion is generally adjacent surfaces defining the aperture and applying a force to the magnetic

armature to deform a portion of the magnetic armature in a region near the aperture so that material of the armature may engage with the reduced cross-section portion of the shaft thereby joining the shaft to the magnetic armature.

5 In accordance with another aspect of the invention, an armature assembly for an electromagnetic actuator is provided and includes an armature composed of an annealed magnetic material. The armature has an aperture therein. A shaft of hardened material has a reduced cross-section portion disposed in the aperture. The armature includes a physically deformed portion adjacent the
10 aperture. The deformed portion is engaged with the reduced cross-section portion of the shaft joining the shaft to the armature.

Other objects, features and characteristics of the present invention, as well as the methods of operation and the functions of the related elements of the
15 structure, the combination of parts and economics of manufacture will become more apparent upon consideration of the following detailed description and appended claims with reference to the accompanying drawings, all of which form a part of this specification.

20

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of an electromagnetic actuator having an annealed armature and a hardened shaft joined by a method provided in accordance with the principles of the present invention; and

FIG. 2 is an enlarged sectional view of the armature and shaft connection of the armature and shaft of the electromagnetic actuator of FIG. 1 made by a pressing operation.

5

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, an electromagnetic actuator is shown, generally indicated 10, having an armature-shaft connection provided in accordance with the principles of the present invention. The electromagnetic actuator 10 includes a housing structure 12 containing a first electromagnet 14 and a second electromagnet 16, which is disposed generally in opposing relation to the first electromagnet 16. An armature 18 is arranged to move between the electromagnets 14 and 16. The armature is carried by a shaft 20. The shaft 20 is coupled to a stem of a gas exchange valve (not shown) in the conventional manner. In the illustrated embodiment, the shaft 20 is solid. It can be appreciated that the entire shaft, or at least a portion thereof, may be hollow. The actuator 10 also includes an upper shaft 21. In the illustrated embodiment, the upper shaft 21 is separate from shaft 20. However, the upper and lower shafts may be made integral.

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In accordance with the principles of the present invention and with reference to FIG. 2, the armature 18 is in the form of a plate having opposing first and second generally planar surfaces 22, and 24, respectively. A generally

cylindrical aperture 26 is provided in the armature 18 along the axis 28 of the armature 18. The armature 18 is composed of a soft magnetic material such as, for example, 3% silicon iron. Other soft magnetic material, such as cobalt iron, may be employed for the armature 18. The armature 18 has been annealed to
5 provide optimum magnetic properties.

The shaft 20 is composed of hardened material, preferably hardened steel having a hardness generally greater than 52 HRC. The steel used for the shaft may be any steel suitable for use as a stem portion of a gas exchange
10 valve of an engine. Thus, the shaft has a hardness substantially greater than the hardness of the armature 18. The shaft 20 is generally cylindrical and sized to be placed into the aperture 26 of the armature 18. The shaft 20 has a reduced cross-section portion 30 which, in the illustrated embodiment, is in the form of a circumferential groove, the function of which will become apparent
15 below.

The method of joining the shaft 20 to the armature 18 will be appreciated with reference to FIG. 2. First, the end of the shaft 20 having the groove 30 therein is inserted into the aperture 26 of the armature 18 such that the groove
20 30 is generally adjacent to surfaces defining the aperture 26. A force is applied via a press 32 in the direction of the arrows in FIG 2. In the illustrated embodiment, the press 32 has an upper member 32' to engage the first surface 22 of the armature 18 and a lower member 32'' to engage the second surface 24

of the armature 18 at a region near the aperture 26. Movement of the upper and lower members of the press 32 causes a portion of the soft magnetic armature 18 to physically deform and move into the groove 30, thereby joining the shaft 20 to the armature 18, thereby defining an armature assembly, generally indicated at 34.

The radius of the groove 30 and the depth thereof are selected to provide the maximum amount of shaft push-out force. In a currently preferred embodiment, the groove 30 has a form radius of 3.5 mm and is 0.5 mm deep from the surface of the shaft 20. One skilled in the art will recognize that other groove geometries, such as trapezoidal, triangular or square, may also be used. Further, multiple grooves may be used in place of the single groove described above.

The press 32 may have upper and lower members 32', 32" with tapered facing surfaces 39', 39" to more efficiently displace material from the armature 18 into the shaft groove 30. For example, in the case of a cylindrical shaft, the facing surfaces 39', 39" may be slightly conical and concave in order to move material of the armature remote from the aperture 26 toward the groove 30. The tapered facing surfaces may have an angle of about 10 degrees from a surface normal to the armature axis 28.

With the invention, only mechanical deformation is required to join the shaft 20 to the armature 18. Thus, the material properties of both the shaft 20

and armature 18 generally maintain their optimum condition, unlike processes such as brazing, which require elevated temperature to join an armature to a shaft. With the method of the invention, the material properties of the shaft 20 and armature 18 are maintained because the pressing operation is performed at
5 a temperature below the tempering temperature of the shaft and below the annealing point of material of the armature 18.

If the shaft 20 has a hollow portion, an insert (not shown) may be brazed, welded or connected in any suitable fashion to a shaft end to provide a tip which
10 may withstand operational impact forces when contacting a gas exchange valve.

It has thus been seen that the objects of this invention have been fully and effectively accomplished. It will be realized, however, that the foregoing preferred embodiments have been shown and described for the purposes of
15 illustrating the structural and functional principles of the present invention, as well as illustrating the methods of employing the preferred embodiments and are subject to change without departing from such principles. Therefore, this invention includes all modifications encompassed within the spirit of the following claims:

What is claimed is:

1. A method of joining a member of annealed magnetic material to a guide member, the member of magnetic material having an aperture therein and
5 said guide member having a reduced cross-section portion, the method comprising:

inserting the guide member into said aperture such that said reduced cross-section portion is generally adjacent to surfaces defining said aperture;
and

10 applying a force to said member of magnetic material to deform a portion of said member of magnetic material in a region near said aperture so that magnetic material engages said reduced cross-section portion of the guide member, joining said guide member to said member of magnetic material.

15 2. The method according to claim 1, wherein said guide member is a shaft and said reduced cross-section portion is created by a circumferential groove in said shaft, said member of magnetic material being in the form of a plate having first and second generally planar surfaces disposed in opposing relation, said aperture being generally circular and disposed along an axis of the
20 plate, said portion of said member of magnetic material being deformed by pressing on each of said first and second surfaces to cause magnetic material to move into said groove.

3. The method according to claim 1, wherein said magnetic material includes silicon iron.

4. The method according to claim 2, wherein said shaft is made from
5 steel.

5. A method of joining an annealed magnetic armature of an electromagnetic actuator to a shaft, the armature having an aperture therein and said shaft having a reduced cross-section portion, the method comprising:
10 inserting said shaft into said aperture such that said reduced cross-section portion is generally adjacent surfaces defining said aperture; and
applying a force to said magnetic armature to deform a portion of said magnetic armature in a region near said aperture so that material of said armature may engage with said reduced cross-section portion of said shaft
15 thereby joining said shaft to said magnetic armature.

6. The method according to claim 5, wherein said reduced cross-section portion is created by a circumferential groove in said shaft, said magnetic armature being in the form of a plate having first and second generally planar
20 surfaces disposed in opposing relation, said aperture being generally circular and disposed along an axis of the plate, said portion of said magnetic armature being deformed by pressing on each of said first and second surfaces to cause a portion of said magnetic armature to move into said groove.

7. The method according to claim 6, wherein said pressing step forms indentations on said first and second surfaces, said indentations having depths increasing with increased distance from said aperture.

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8. The method according to claim 5, wherein said magnetic armature includes silicon iron.

9. The method according to claim 8, wherein said shaft is made of steel.

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10. A magnetic armature and shaft assembly made according to the method of claim 5.

11. An armature assembly for an electromagnetic actuator, the armature assembly comprising:

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an armature composed of an annealed magnetic material, the armature having an aperture therein; and

a shaft having a reduced cross-section portion disposed in said aperture,

wherein said armature includes a physically deformed portion adjacent said aperture, said deformed portion being engaged with said reduced cross-section portion of said shaft joining said shaft to said armature.

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12. The armature assembly according to claim 11, wherein said shaft is of hardened material and said reduced cross-section portion is a circumferential groove in said shaft, said armature being in the form of a plate having first and second generally planar surfaces disposed in opposing relation, said aperture
5 being generally circular and disposed along an axis of the plate, a portion adjacent said aperture of each of said first and second surfaces defining said deformed portion.

13. The armature assembly according to claim 11, wherein said armature
10 includes silicon iron.

14. The armature assembly according to claim 11, wherein said shaft is made of steel.

15 15. An armature assembly for an electromagnetic actuator, the armature assembly comprising:

an armature composed of an annealed magnetic material, the armature having an aperture therein;

a shaft of hardened material, a portion of said shaft being disposed in
20 said aperture; and

a connection joining said shaft to said armature, said connection being formed at a temperature below a tempering of said shaft and below an annealing point of said armature such that magnetic properties of said armature and a

hardness of said shaft are generally not affected as a result of said shaft being joined to said armature.

16. The armature assembly according to claim 15, wherein said shaft
5 has a circumferential groove therein, said armature being in the form of a plate having first and second generally planar surfaces disposed in opposing relation, said aperture being generally circular and disposed along an axis of the plate, a portion adjacent said aperture of each of said first and second surfaces including
10 a deformed portion engaged with said groove, said deformed portion and said groove defining said connection.

17. The armature assembly according to claim 15 wherein said armature includes silicon iron.

15 18. The armature assembly according to claim 15, wherein said shaft is made of steel.

FIG. 1

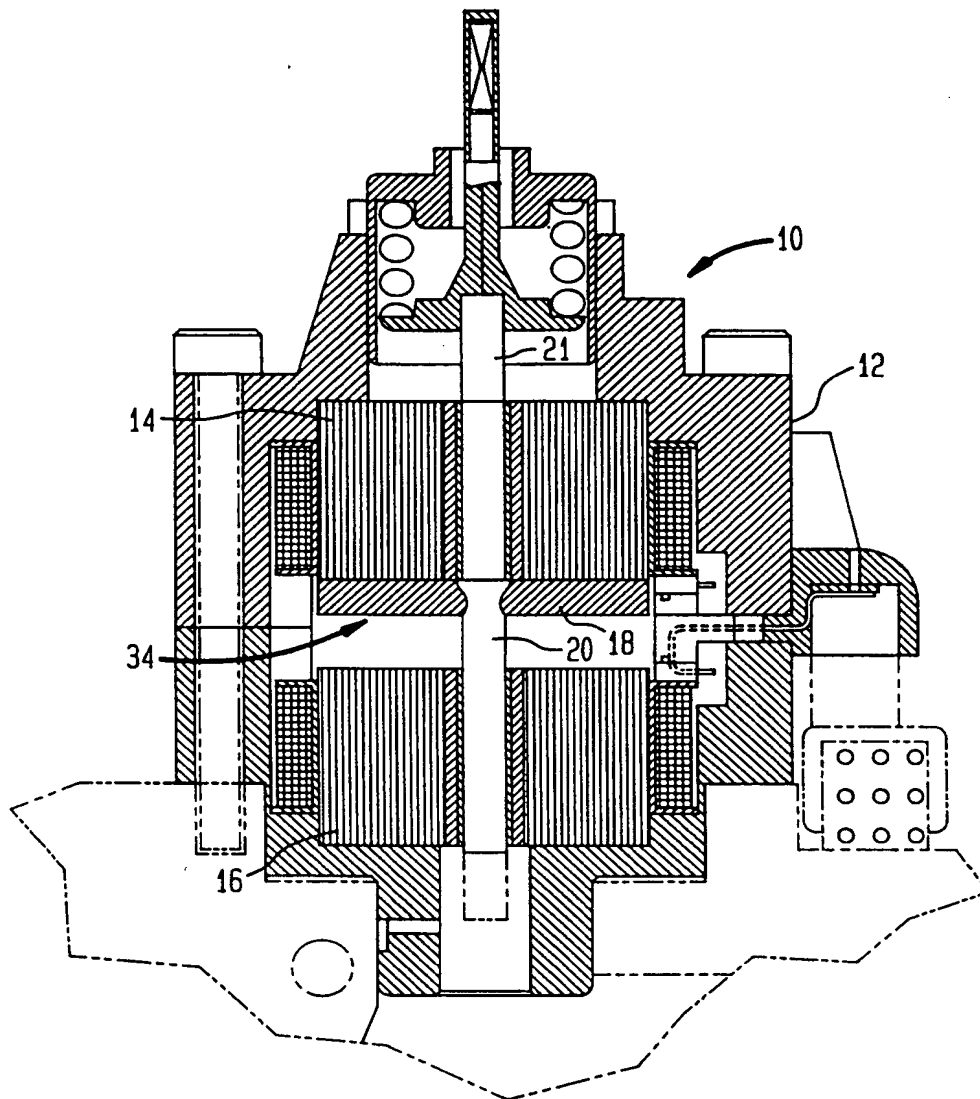
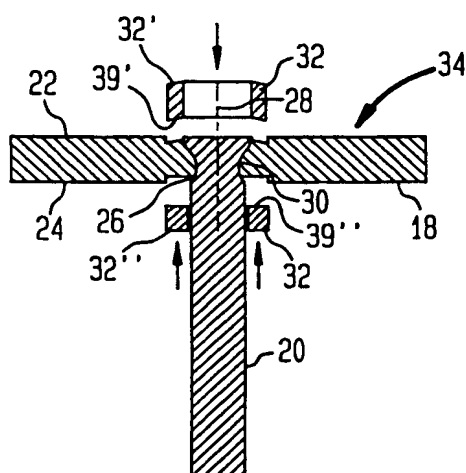


FIG. 2



INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/22524

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H01F7/127 H02K15/02 F01L9/04

According to International Patent Classification (IPC) or to both national classification and IPC

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 300 908 A (STONE ET AL.) 5 April 1994 see column 1, line 5-25 see column 2, line 39 - column 3, line 12; figures 1-3	1-6,8-18
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X	see column 8, line 49 - column 9, line 2; figures 6,11,13	11,15
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